Wind and Seismic Effects

Proceedings of the 30th Joint Meeting

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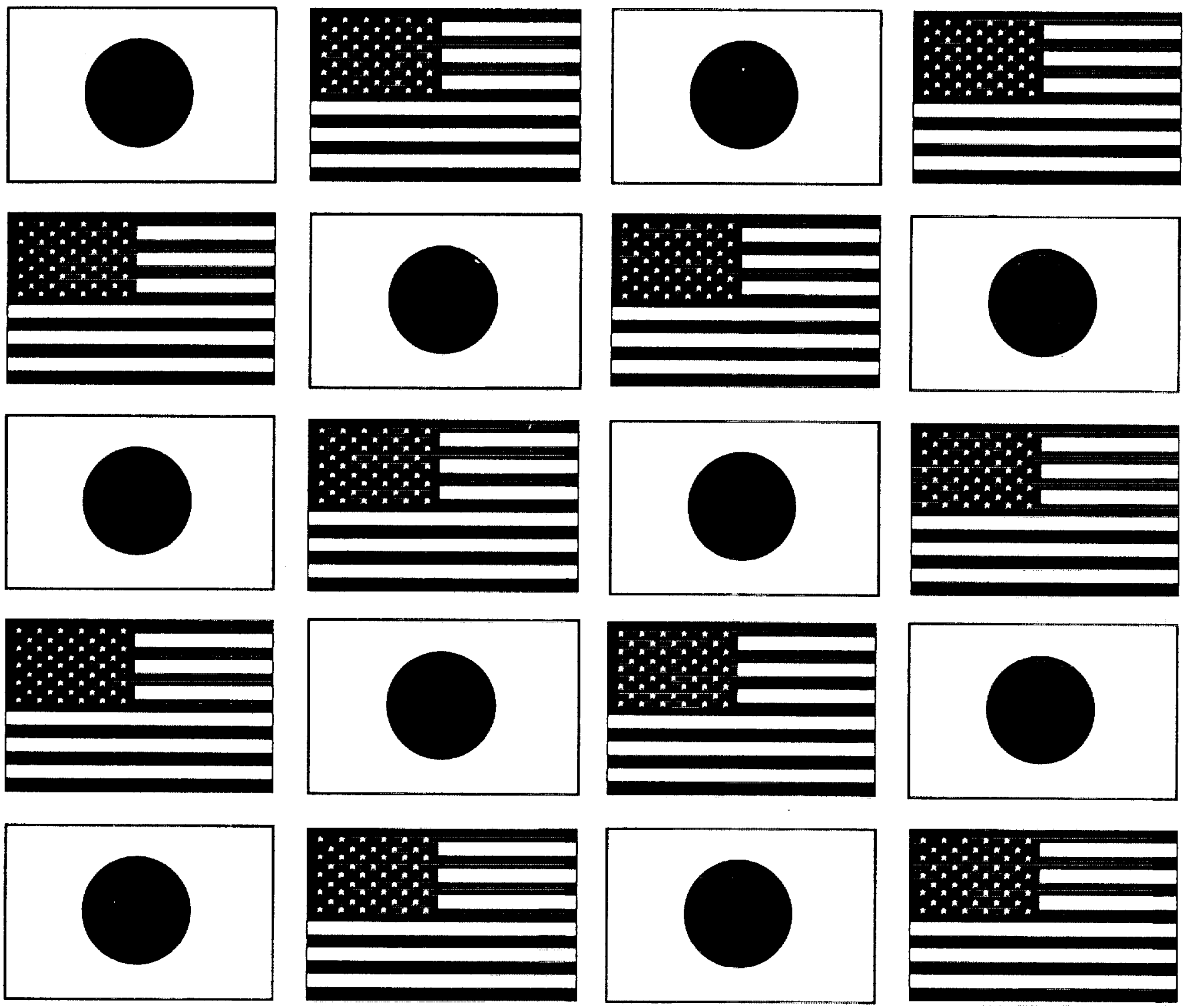

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Wind and Seismic Effects

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REAL TIME INFORMATION ACQUISITION and DISSEMINATION

Geospatial Analysis Support to Natural Disasters

By

William E. Roper [1]

ABSTRACT

Natural disasters have a major impact, globally and within the United States (U.S.) causing injury and loss of life, as well as economic losses. To better address disaster response needs, a task force has been established to leverage technological capabilities to improve disaster management. Geospatial analysis is one of these important capabilities. A cross section of geospatial technologies applicable to disaster management are presented. These include: 3-D visualization, hyperspectral imagery, use of spectral libraries, digital multispectral video, fluorescence, radar imaging systems, photogeologic analysis, shaded relief imagery, differential global positioning system, and geographic information systems. A sample of satellite and sensor systems currently available is presented.

KEYWORDS: disaster management; mapping; hyperspectral; geospatial; spectral library; radar imaging; fluorescence; GIS; photogeologic analysis; GPS; satellite sensors; shaded relief; 3-D fly through.

1. INTRODUCTION

Natural disasters are a constant threat to mankind on a global scale. Global disaster costs are continuing to rise. Annual global economic costs related to disaster events average $440 billion per year (World Disaster Report, 1996) with floods being the major cause (Figure 1). In the U.S., the number of lives lost due to natural disasters has been decreasing over the last several decades, largely because of advances in disaster indication and warning capabilities. In terms of damage to property, however, the trend is reversed. For the period 1992-1996, the average cost of natural disasters in the U.S. has been $54.3 billion, with hurricanes and earthquakes tied as the leading cause (Figure 2). These rising costs are the combined result of increased urbanization, particularly in high-risk coastal areas, and the increased complexity and size of our infrastructure.

The loss of life and property continues to rise in many regions of the world because of these events. One example is the Bangladesh weather event of 1970, when a tropical cyclone slammed into its delta region killing 300,000 people (Tobin and Montz, 1997). The crop losses were estimated at $63 million, and more than 280,000 cattle were drown (Burton, Kates, and White, 1993). The rich delta soil is an agricultural resource that still draws people to settle there, therefore a recurrence of this type of weather event could likely pose a similar disaster.

This paper will focus on geospatial analysis and some of the specific developments in this rapidly changing area that can assist the disaster manager. There has been significant capability growth in the geospatial areas of remote sensing, spectral analysis, global positioning systems (GPS), geographic information systems (GIS), and modeling and simulation techniques (Roper, 1997). Each adds important value in characterizing infrastructure, risk areas, disaster zones, and control points that are essential to rapid deployment of scarce resources in the most effective manner.

2. GLOBAL DISASTER INFORMATION NETWORK

In February 1997, Vice President Albert Gore sent a letter to key Federal departments and agencies

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requesting that senior officials discuss the feasibility of establishing a global disaster information network. In response to this request, a Disaster Information Task Force was established to evaluate the needs and issues, examine the feasibility, and outline a phased, integrated approach to address this important global need (Disaster Information Task Force Report, 1997).

There has been considerable effort expended in developing and coordinating activities in the U.S. Federal government over the last 1 1/2 years relating to the Global Disaster Information Network (GDIN). Some of the initial Geospatial-related efforts focused on the integration of archival and real-time data sets, and the adaptation of new and emerging technologies. Ongoing activities of the Disaster Information Task Force related to geospatial technology include directed technology support, information integration, and modeling technologies for disaster effects. The specific recommendation for the directed technology area includes development of approaches to integrate new and emerging tools and technologies for modeling, simulation, data fusion, etc., for use by disaster managers and planners.

It is important to consider the application of geospatial data and analysis across the comprehensive Disaster Management Cycle. This basic four-phased framework of mitigation, preparedness, response, and recovery, when integrated with GDIN capabilities, can be a strong supplement to current disaster support functions (Figure 3). Geospatial information can make a critical contribution to the disaster management community through enhancing the definition, identification, accuracy, and availability of essential information for community resilience.

3. GEOSPATIAL RESEARCH COMMUNITY INVOLVEMENT

The flow of disaster related information can be conceptually shown as a seven step process as shown in Figure 4. The geospatial research community may have a role in each of these steps, depending on the particular disaster situation. This could include assistance in defining the problem through current image analysis. Assistance in determining collection and analysis methodologies assists in defining the requirement. A key area of support is providing supporting data in the form of maps, imagery, and spectral information.

An even more important support area is data exploitation. This includes the processing of digital data, image integration, feature classification and attribution, classification output, accuracy assessments, and post-processing operations. It is the most technically challenging step in the process. The decision support phase includes geospatial visualization, merged data analysis, and specialized decision support products. This involves the synthesis of data types in order is generate data layers (such as, soils, vegetation, terrain) along with models and simulation techniques that use the various data layers.

It is during this phase that the concept of virtual forums could take place. These forums would allow expert input from multiple locations to be jointly focused on problem solving for the disaster situation. Within the geospatial community this could include virtual fly-through support showing the impacts of possible decisions on the natural environment, the built environment, and on the population, including those with special needs. It also could include analysis of changing situational information, and image-based change detection and analysis.

In the final two phases, tailored map products and GIS overlay information can be used as integral parts of directives and guidance to disaster mangers in the field. These specific products could be maps delineating evacuation routes, area identification for damage assessments, or point locations for water distribution.

The geospatial research community has typically been interdisciplinary, including the natural sciences, engineering, architecture, land use planning, photogrametry, etc. However, in the disaster management arena, broader interdisciplinary teaming will be required. This could include public policy and health specialists at the Federal, state, and local level. It may include other medical specialists, police, national guard, and communications experts.

The greatest potential for loss reduction is during the mitigation phase (Disaster Information Task Force Report, 1997), when communities can be made more disaster resistant. The largest share of costs, however, are directed toward the recovery phase, where good mitigation principles also need to be put into practice rather than just rebuilding to be impacted by a similar disaster in the future. geospatial products and location specific tools developed during the response phase of the disaster may be excellent vehicles for planning and implementing effective mitigation.

4. GEOSPATIAL TECHNOLOGY OPPORTUNITIES

There are a number of new and evolving technologies and capabilities in the geospatial area that have application to disaster management. Some of these techniques assess and present data in new and innovative ways. Others are possible today because of new sensor and data processing capabilities.

4.1 DrawLand Visualization

DrawLand is one of the software programs used to support terrain visualization research. It was developed by the U.S. Army Topographic Engineering Center (TEC) and continues to be refined and used in research and operational applications. TEC has recently entered into a cooperative research and development agreement with ERDAS Corporation to make DrawLand available commercially as part of the ERDAS Imagine software program. Its release is planned for late in 1998.

DrawLand's main input is digital terrain elevation data (DTED), which can load the program into memory directly from CD-ROM. The user can specify the geographic area to be loaded. Given the southwest corner and the size of the cell, DrawLand searches for the appropriate files and can combine data from several files to produce a 3-D terrain scene. A sample scene over a mountainous valley terrain is shown in Figure 5. A 1 minute digital fly-through of this geospatial database will be presented during the oral presentation.

DrawLand has been used to visualize imagery from a variety of sources to include: Landsat, SPOT, high-altitude aerial photography, and Interferrometric Synthetic Aperture Radar (IFSAR). It also can use data from commonly used commercial software for disaster management support, such as ArcInfo, ArcView, and ERDAS Imagine. DrawLand can drape raster data over digital terrain elevation data within minutes to create the appearance of a 3-D map.

In the interactive or flight mode, the terrain is displayed as a reduced resolution polygon surface. Users can adjust the resolution and vary the rendering mode to suit their purpose (e.g., wire frame for speed, photo texture for realism). Coordinates, altitude above Mean Sea Level, distance above ground, yaw, pitch, and roll, are displayed for the viewpoint or for a model. The software also provides mission planning tools, such as masked area depiction, line-of-sight calculations, and flight path design, and can include unit symbols or polygon models of objects based on ground locations. All of these tools could be tailored to the particular disaster management situation and requirements.

During flight mode, the movement of the user's viewpoint can be recorded, as can the movement of any selected model that is being controlled. The animation can be recorded one frame at a time to a VCR tape or various digital movie formats. Model movements also can be played back in real time.

4.2 Hyperspectral Imagery

Hyperspectral remote sensing combines imaging and spectroscopy in a single system that includes data sets and processing methods. Hyperspectral data sets are generally composed of about 100 to

200, or more, spectral bands of relatively narrow bandwidths (5-10nm). The spectral range of interest of these data sets usually encompasses the portion of the spectrum dealing with reflected energy from the visible to the short-wave infrared (0.4 to 2.5μm). Hyperspectral airborne sensors can image ground materials in many bands of relatively high spectral resolution in a digital mode (Samuel Barr, 1997). Figure 6 illustrates this as applied to the Jet Propulsion Laboratory's Airborne Visible Infrared Imaging Spectrometer (AVIRIS) sensor. If a stack of picture elements (pixels) of a single target were extracted from the data set and plotted out as a function of wavelength (Figures 6 and 7), an average spectrum of all of the materials in the pixel would result. Because of the 3-D nature of these data sets, they are generally referred to as image cubes as depicted in Figure 8.

The large amount of data in the hyperspectral image cube may provide an important new tool in disaster management. However, there is still much to learn about the practical application of this technology. An example application, the mosaic image of Landsat Thematic Mapper data and AVIRIS data of a portion of the Bighorn Basin, northeast of Worland, WY, U.S., is shown in Figure 9. This image illustrates the synergy between large area coverage by satellite sensors and targeted airborne imaging hyperspectral data. The background image is a roughly 20 by 30 km portion of a Landsat Thematic Mapper color composite of bands 3,2,1 (true color), saturation-enhanced to contrast with the AVIRIS overlay. North is shown toward the bottom of the page. The 3-D hyperspectral image cube demonstrates the high spectral resolution nature of the AVIRIS data, which has 224 bands covering the spectral range of 0.4 - 2.5 μm at 10 nm resolution. The AVIRIS cube face is a true color composite using bands 31, 19, and 10 (0.66μm, 0.55μm, and 0.45μm). The cube sides represent color-coded reflectance spectra for the pixels along the edges of the image. The color scheme of black, blue, green, yellow, red, and white indicates increasing reflectance (ENVI internet home page, 1998). These data are used together in a hierarchical strategy in this application for geologic mapping and exploration using Landsat to provide an overview and to locate targets for more detailed study. The hyperspectral data are used for mineral species identification and abundance mapping, and field mapping and field spectroscopy for verification. Similar analysis of this kind of geospatial data might be used to identify earthquake, landslide, or soil liquefaction potential in the mitigation phase of disaster management. It is important to note that the commercialization of hyperspectral systems will soon make these data widely available. Commercial aircraft systems are in use today, and several satellite systems are planned for deployment by the year 2000.

4.3 Socet Set 3-D Visualization

Socet Set is a geospatial analysis software system jointly developed by the TEC and the private sector. Some of the main features of the Socet Set System are to triangulate images from a variety of sensors, automatically generate elevation data at almost any resolution, generate 3-D features, and generate orthophotos. Near real-time fly-through is achieved using Rapid Scene software in conjunction with Socet Set. Both will run on the Sun computers in near-real time, and an NT version is expected to be available this fall.

The next generation will be Rapid Scene Open Graphics Library (OGL), which will operate real time on a Pentium PC running the NT operating system. The advantages of this NT version are that the hardware and software required are much less expensive. A top-of-the-line graphics card, costing approximately $2,500, and a 200 MHz Pentium will perform impressively. Another advantage is that the software uses the native Socet Set database, therefore no conversion process is needed.

This software gives the user the capability to properly register (triangulate) the following sensors: standard aerial digitized frame imagery, SPOT, LANDSAT, RADARSAT, Japanese Earth Remote Sensing Satellite, Omni, generic panoramic, and generic close range. The Socet Set Development Toolkit enables a programmer to insert additional math models into the software to perform registration in conjunction with other sensors.

Whenever stereo imagery is available for the above sensors, one can generate high-resolution elevation data using the Automatic Terrain Extraction (ATE) module of the Socet Set software. Thus, it is possible to generate data that has a post spacing of 1m, if so desired. The horizontal and vertical accuracy of this data depends on a number of factors, such as the resolution of the imagery, the type of control points used, and the convergence angle of the stereo images. Further applications, such as terrain shaded relief images, and line of sight analysis, can be done within Socet Set. The line of sight capability provided within Socet Set also integrates buildings and trees into the analysis (if constructed in the feature extraction module described below).

Where the elevation data generated using automatic terrain extraction does not meet quality control criteria, a full suite of interactive editing tools is available to manually update the data. Typically this may be required over features such as lakes where there is little contrast in the imagery for the automatic correlation process to perform efficiently.

Another key capability is the ability to create digital orthophotos where the displacement is accounted for because of terrain relief. This in turn can be made into a map substitute with grid lines and feature annotation overlain for quick updates of maps in emergency situations.

The Feature Extraction module enables the user to collect arial, line, and point features while in a 3-D stereo environment. Thus, a true coordinate exists for every point digitized. The feature extraction tool also allows the construction of 3-D wire frame models that high resolution simulator fly-through packages depend on to make the generated scenes appear realistic. The wire frames can be exported into several other software packages for further exploitation.

A module called Image Perspective Transformation (IPT) is available, which renders high resolution fly-throughs in non-real time. Although this is not a real-time interactive fly-through capability, several features are still unique on this module. The software allows the user to texture the rendered scenes from multiple images that are registered in an automated fashion. Thus, a building can have texture on four sides and the roof from five different images, and the user does not have to manually register each image. Since the images have already been tied to the ground, and with each other photogrammetrically, all of the image texture from all of the images will correctly cover the appropriate building face as shown in Figure 10 (a 1 minute dynamic fly-through was shown in the oral presentation).

As mentioned previously, Socet Set is one of the premier database development tools for constructing high resolution fly-throughs. All of the above tools give the user the ability to put together, from two or more images, a complete, accurate database. The interface with the Evans and Sutherland, Inc., simulator databases is a final important step in allowing the database to maintain its integrity. Typically, in the translation of data from one software package to the next, important attributes are lost or altered, decreasing the accuracy and usefulness of the database.

The applications of these tools are numerous. TEC has done work to help locate where World War I-era munitions were buried in the Spring Valley neighborhood of Washington, D.C., by triangulating images taken in the 1920s with modern imagery. This gave analysts the ability to precisely locate where potential burial locations existed in a modern coordinate system.

For disaster assistance Socet Set can create high resolution data sets from a wide variety of image sources. Using Rapid Scene with Socet Set, 3-D depictions of the terrain and building features can be created. The disaster manager could virtually walk into the situation to conduct assessments and planning activities.

In summary, this software provides the ability to provide rapid, high resolution databases that can support a multitude of applications in today's dynamic environment.

4.4 Spectral Library Database Program

The ever increasing amount of data and spectral information that is in current databases, and the future flood of data from hyperspectral sensors, will require a more usable spectral database library for more effective interpretation and development of products. The possibility of an open cross platform web-based spectral library is a very powerful concept. It could provide an invaluable tool for future spectral related research, and greatly reduce the time and resources necessary to produce useful products from spectral data. The design of such a library would require careful assessment of user needs, minimum data characterization requirements, and easy input and access controls.

TEC currently has more than 5000 spectral signatures, as well as signatures from other organizations in its existing database catalogue. These include visible-near infrared, fluorescence and thermal spectra obtained from field, laboratory and imagery. These data are being organized and characterized into an interactive library structure. The initial design concept is shown in Figure 11a. Upon completion, the library is intended to have multiple scientific tools for viewing spectral data and performing numerical and statistical tools for viewing data and performing numerical and statistical analysis. The distributed system will house the database and scientific tools on different servers and possibly different platforms. The system structure will be transparent to the user who will access the data over the Internet via a web browser or similar interface. A prototype of the computer metadata display and spectral signature is shown in Figures 11b and 11c. This is an activity where we will be seeking broad collaborative partnerships to build a comprehensive and useful spectral data library.

4.5 Digital Multispectral Video

Digital Multispectral Video (DMSV) is an immerging technology that has strong potential application to disaster response and mitigation activities, as well as many other site characterization applications. The DMSV is an airborne instrument that acquires high spatial and temporal resolution multispectral (visible to near infrared) imagery. This technology is very useful for accurately characterizing complex tidal, atmospheric, geologic, anthropogenic induced change, and geometric events that would be difficult to measure with other systems.

The surface characterization application of DMSV, shown in figures 12 and 13, illustrates the system's tuning ability for detection of whether shoreline or aquatic vegetation are predominate in an environmental monitoring application. In Figure 12 the location and density of shoreline vegetation is very evident, but only the presence or absence of aquatic vegetation is observable using the 0.75, 0.66, and 0.55 micrometer bands. If a band combination of 0.77, 0.75, and 0.55 micrometers is used, the density of aquatic vegetation can be observed (Figure 13).

The DMSV system is comprised of four charged coupled device (CCD) cameras with 12-mm focal length lenses, a ruggedized 486 PC, 32 Mb of RAM, a 500 Mb hard disk, and a 4-Mb AT frame-grabber board. Each of the four cameras were fitted with a 25-nm band pass interference filter. These filters were centered at 450-nm, 550-nm, 650-nm, and 750-nm, respectively. The four bands are captured simultaneously and stored on internal RAM. Each 8-bit, 740 by 578 pixel four-band frame is a little over 1.7 Mb in size, which allows for the collection of 17 frames before the data must be transferred to the PC hard drive.

4.6 Fluorescence

Fluorescence is the emission of light or other electromagnetic radiation of longer wavelengths by a substance as a result of the absorption of some other radiation of shorter wavelengths. Fluorescence spectroscopy is a common technique used in many scientific fields including geology, biology, and medicine, and more recently, remote sensing. Fluoresced energy is considered to contain more information about a features structure than reflected energy. Thre are two primary techniques to obtain fluorescence information, active fluorescence and passive fluorescence. Active fluorescence is the more common method in which the excitation energy is supplied by some source other than the sun. Normally, this is a laser or some other monochromatic light source. Passive fluorescence uses solar radiation as the excitation source and emission can only be measured in solar absorption regions, also called Fraunhofer lines (J. N. Rinker, 1997).

TEC is active in many areas of fluorescence research. Currently, there are two operating bench-top spectral fluorometers being used in this research. One is a portable passive spectro-fluormeter. The second is a new Laser-Induced Fluorescence Imaging System (LIFI), which will begin operation this summer. The LIFI instrumentation is used to derive basic relationships between an objects physical state and fluorescence response. Fluorescence sensors have been used very successfully to study petroleum spills, plant stress, and aquatic chlorophyll.

The significance of fluorescence signatures for petrochemicals, such as oil, is shown in Figures 14a and 14b. Figure 14a represents the fluorescence frequency distribution of an organic garden soil. When only one drop of oil is mixed into the soil, the frequency distribution is dramatically changed. This same characteristic could be used to remotely detect, and precisely locate, small underground gas and oil leaks following earthquakes and other natural disasters.

There are a number of ongoing collaborative research projects in the fluorescence area between TEC and other groups and agencies, including U.S. Department of Energy, Disney's Epcot Center, and the Virginia Institute of Marine Science. Much of the work in this area will be incorporated into the spectral library program.

4.7 Radar Systems

The state-of-the-art in exploiting interferometric synthetic aperture radar (IFSAR) for terrain information is advancing rapidly, and provides significant potential for use in crisis support operations. Unlike conventional SAR imagery, IFSAR data permits the generation of rectified SAR images co-registered with an accurate terrain elevation file. In addition, this imagery can have an absolute geographic accuracy of 3m RMS or less. The rapidity with which IFSAR data can be collected and processed over wide areas, and the all-weather, day-night capability, offers significant potential for providing direct support to crisis situations, as well as enhancing the performance of spectrally-based assistance. In addition, IFSAR terrain elevations can be employed to rectify hyperspectral imagery, allowing for the registration of radar and hyperspectral imagery in the ground plane, thus providing an improved database for the extraction of topographic information (Figure 15).

The contractor for this program, titled Interferometric Synthetic Aperture Radar for Elevations (IFSARE), was the Environmental Research Institute of Michigan (ERIM). Their efforts resulted in the fabrication of an interferometric radar system integrated with a GPS internal navigation system which was mounted on a Learjet 36A. The National Aeronautic and Space Administration jointed with the Jet Propulsion Laboratory in California to develop the processing software and the ground-processing environment. This software and ground processing capability has now been transitioned to the Intermap Technologies Company, and is available for commercial applications.

This effort represents a convergence of technology developed by a large number of investigators, only a few of whom are referenced above, and a pressing need for low cost, fine resolution, highly accurate terrain elevations for a wide variety of applications. It is critically dependent on recently devised GPS capabilities and the advent of high-speed data processing capabilities.

In summary, the IFSARE system for collecting digital elevation map information, at low cost, is just now becoming available for application to problems such as disaster responses. It is anticipated that significant IFSAR data collections will occur in the next few years. Ongoing activities within TEC are focused quantifying the performance of IFSAR techniques. Additional work will be done for demonstrating the capability to merge radar and hyperspectral data. There is significant potential for application of IFSAR data in all four phases of disaster management.

4.8 Photogeologic Analysis

Historical Photogeologic Analysis using Aerial Photography allows mapping of terrain features, such as fractures or the surface expression of these fractures, which are called lineaments. Fractures in the bedrock are important to identify because they often serve as contaminate conduits. They are the "doorways" that allow surface contamination to enter the ground water system (Figures 16, 17, and 18). Changes in land use and land cover often obscure the surface expression of these fractures in the underlying bedrock.

Additionally, knowledge of the location, direction, and length of fractures significantly improves the speed and results of costly Geophysical Studies by correct alignment of their survey track planning. Also, surveys that, for lack of good planning input, do run parallel to fractures, often produce erroneous data.

In an area of Karst terrain, photogeologic analysis identification of historical sinkhole depressions can be used. These features also frequently "disappear" with changes in Land Use and Land Cover. Like fractures, sinkholes serve as a direct contaminate conduit for connecting the surface with the ground water system.

Photogeologic analysis can be applied to the identification of historic seismic shear zones, and to the geo-positioning of these features onto current maps and GIS products. Such products could be used in all phases of disaster management.

4.9 Shaded Relief Products

Shaded relief image and vector products are intended to give the user a better perspective of the ground terrain of interest. Figure 19 shows the registration of a 20-degree angle hyperspectral image with a 90-degree vertical hyperspectral image of the same area.

The co-registered image gives the perspective of higher resolution and near 3-D presentation. In this application, the same land-use color coding was used for each image. The classification was done using automatic delineation of roads, grasses, trees, water, etc., using only the spectral response of those materials.

4.10 Differential Global Positioning System

Techniques developed to process signals from two GPS receivers operating simultaneously can be used to determine the 3-D vector between the two receivers. These techniques are known as Differential GPS (DGPS), and can be used to produce results ranging from millimeters to a few meters, depending on the method used. DGPS can easily achieve centimeter-level accuracy using the carrier phase information broadcast by the GPS satellites. The On-The-Fly (OTF) system has been under development at the TEC since the late 1980s. This system provides real-time 3-D positions with horizontal and vertical accuracy of 3 cm over ranges up to 20 km from a single reference station without static initialization.

This high accuracy DGPS technology, developed at TEC, is being used aboard various platforms (i.e., airboats, helicopters, and wheeled vehicles) to support the U.S. Geological Survey's efforts to accurately map the Everglades National Park and surrounding suburban areas. This mapping project is in direct support of the South Florida Ecosystem Restoration Initiative, which involves various federal, state, and local agencies. Data collected for this effort will be used to produce water flow models to accuracies that were previously impossible,and, thus, will enable the assessment of the effect of flood control structures and urbanization on this fragile natural ecosystem.

The DGPS technology also is being used to very accurately measure tides at the boat or inlet location without the need to construct a physical tide measurement station. The first application of this system is underway at Kings Bay inlet in South Georgia (Figure 20). This could dramatically change the way tides are measured. It also has application to all disaster management situations where rapid accurate knowledge of tide levels is needed to better plan or respond to the emergency.

4.11 Geographic Information Systems

Geographic Information Systems (GIS) collect, manage, analyze, and display geographic data. While GIS has much in common with other information systems technologies, it is unique in its ability to process information about the location of geographic features (Board of Earth Sciences and Resources, 1997). Because of this emphasis on location, GIS technology has found application in a wide variety of fields, including banking, precision farming, real estate, forestry, military operations, and emergency management.

A key feature of GIS is its ability to integrate data from different sources. GIS data comes from maps, satellite imagery, aerial photography, survey data, pictures, and text (Berry, 1995). GIS software takes this disparate information and puts it in a common framework.

The power of GIS lies in its sophisticated tool set for analyzing geographic information. Distance, direction, and area measurements can be calculated. Map layers can be overlaid and combined in different ways as shown (Figure 21). Buffers inside or outside of features can be generated. Shortest paths through a network, or across a surface, can be calculated. Relationships among features, like connectivity, adjacency, or nearness, can be determined.

The analysis functions of a GIS can be combined in powerful ways. A GIS can answer complex queries, such as "Find the closest support vehicle near point A, and route it along the shortest path between its current location, point A and point B. Choose the path that avoids roads within 200 yards of the floodplain, and roads that are currently under construction."

GIS technology is particularly relevant to emergency management and can be used in all four phases: mitigation, preparedness, response, and recovery. For mitigation, a GIS can show the locations of hazards and analyze the vulnerability of people and property under different potential disaster scenarios. For preparedness, a GIS can map the locations and characteristics of resources available to respond to a disaster. Evacuation routes can be predetermined for different disaster scenarios. When disaster strikes and the response phase starts, GIS can support the identification, location and deployment of resources. Adjustments can be made in real time to reflect the changing hazard, infrastructure, or availability of resources. For short-term recovery, GIS is a valuable tool used during damage assessment, and for the creation of documentation required for relief support. Finally, GIS can be used for redevelopment or relocation planning as part of a longer-term recovery effort.

An example application of GIS in the project management area is the Civil Works Digital Project Notebook (DPN). The objective of the DPN was to develop a Windows-based software package capable of replacing the 38 3-in binders of Civil Works project maps and information, and enabling geographically referenced queries of project information. The DPN is composed of a series of functions to display information about the Civil Works projects referenced to district, division, congressional district, state, and national boundaries. Each project, defined as a point on a map of the U.S., has associated tabular data, such as name, type, status, funding amount, etc., that can be displayed on command. In addition, there is a linked description, large-scale map, and picture associated with each project as shown in Figure 22. The project information used in the DPN was compiled from the hard copy project notebooks and/or district input.

ArcView, a commercial-off-the-shelf GIS package from ESRI, Inc., was used as the fundamental building block of the DPN. The ArcView-based DPN displays various themes of importance to HQ personnel, district and division personnel, and congressional staffs, who are accustomed to using the traditional bound document. These themes are displayed on a map of the U.S., which includes projects (represented by dots), major waterways, major roads, district boundaries, division boundaries, congressional boundaries and state boundaries. The user can query projects based on geographical area, type, category class subclass, status, funding and/or name. The menu was designed to be simple and usable by those with no ArcView experience, and minimal computer experience.

5. SATELLITE SENSOR INFORMATION

There are a number of satellite based sensors currently available for image-based product production. A sampling of current satellites and some near-term projected systems scheduled for deployment is shown in Figure 23. Landsat and SPOT were the sources of space-based imagery during the 1970s and 1980s. Spatial resolution for these systems ranged from 120 to 10 meters, with most applications using 30-m spatial resolution data during that time frame. Revisit times for these systems were 16 to 18 days for Landsat, and 26 days for SPOT (Remote Sensing Users' Guide, 1997).

More recent systems have added all-weather capabilities with RADARSAT and IFSAR in 1995, and spatial resolutions down to 5 m. Revisit times also decreased to every 2 to 9 days. The EarlyBird sensor, launched in late 1997, had a spatial resolution of 3 m and a 2 to 3 day revisit time. Unfortunately, communication with the sensor was lost and no images were ever received from the system. The follow-on sensor system, by EarthWatch, Inc., is QuickBird, which is scheduled for launch in late 1999.

Space Imaging, Inc, plans to launch a new satellite, in June of this year, that could add significant imagery resources. It will have a 1-m spatial resolution in the panchromatic mode and a 2- t0 4-day revisit capability. In the multispectral mode, its spatial resolution will be 4 m using 4 bands in the 0.45- to 0.90-um range.

6. CONCLUSION

The opportunity to leverage technology in the geospatial area to assist in disaster management has never been greater. There are many tools and processes currently in use that have not been applied to assist in disaster management. Examples include the application of hyperspectral sensor data, use of digital multispectral video, and geospatial 3-D fly-through analysis. All of these capabilities could support and enhance the information available to the disaster management decision maker.

There are exciting changes expected to occur during the next few years in the geospatial data community. New aircraft and space-based sensor systems are planned that will revolutionize the spectral and spatial resolution of data available for commercial applications. There will be challenges, particularly in the data processing and management area, because of the extremely large spectral databases these new sensors will generate.

The spectral library project also provides an opportunity to expand cooperatively our global understanding of the vegetative and geologic spectral makeup of the earth. The baseline data from this effort would be invaluable in conducting change analysis assessments following a natural disaster, such as an earthquake or hurricane. Using some of the analysis tools described earlier, the analysts and decision makers could virtually walk into the disaster situation. Other spectral technologies, such as fluorescence, could be used to precisely locate very small underground gas and oil leaks remotely.

Within the next decade, there may be the ability to better harness geospatial analysis capabilities to help reach the vision for the cooperative exchange of timely, relevant information useful during all phases of disaster management--to save lives and reduce economic loss.

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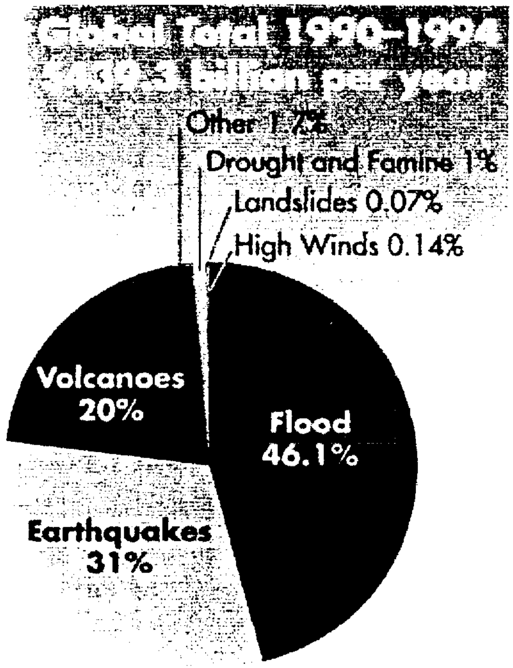

Figure 1: Global Natural Disaster Costs and Distribution by Event Categories (GDIN Task Force Report, 1997)..

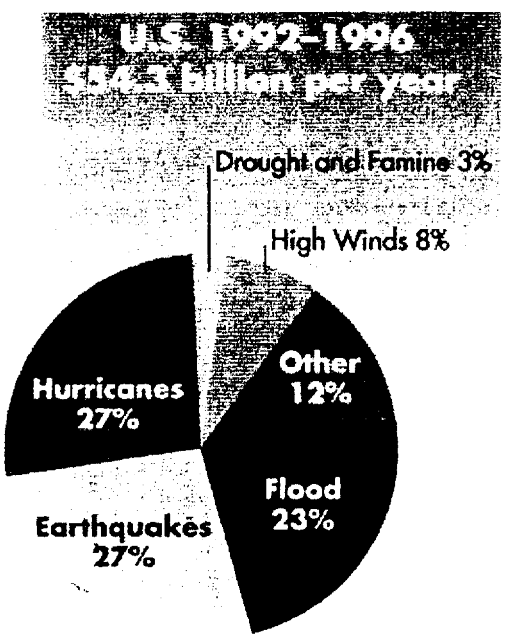

Figure 2: United States Natural Disaster Costs and Distribution by Event Category (GDIN Task Force Report, 1997).

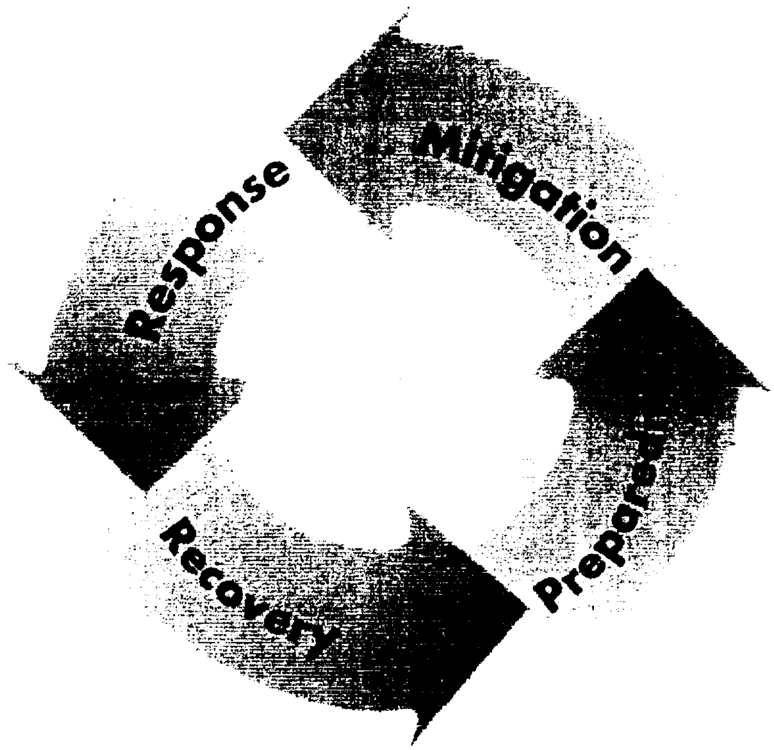

Figure 3: The Four Fundamental Elements of Disaster Management.

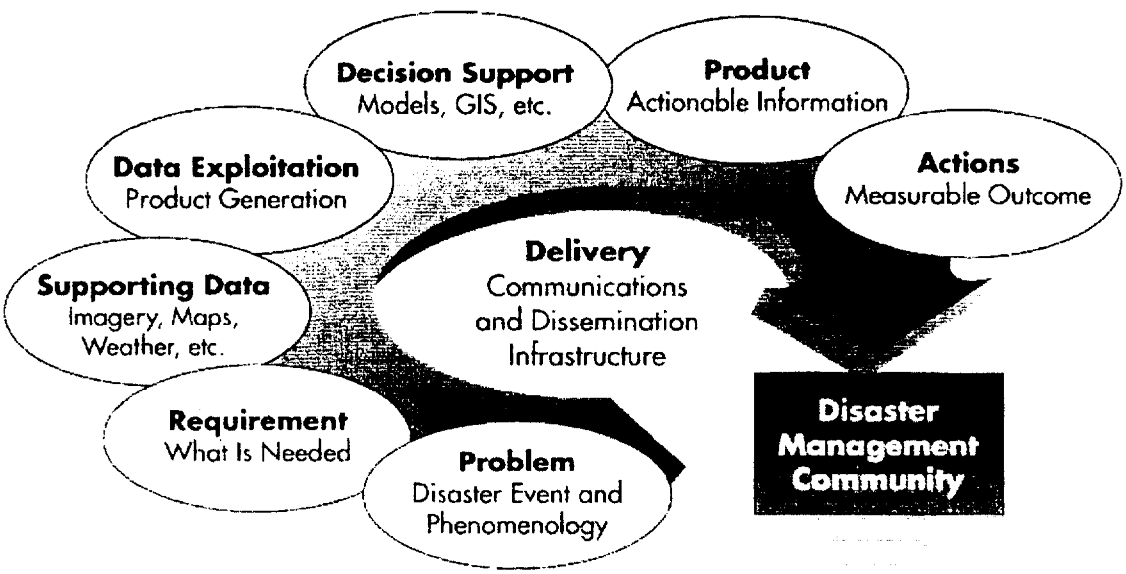

Figure 4: Elements of the Disaster Management Process (GDIN Task Force Report, 1997).

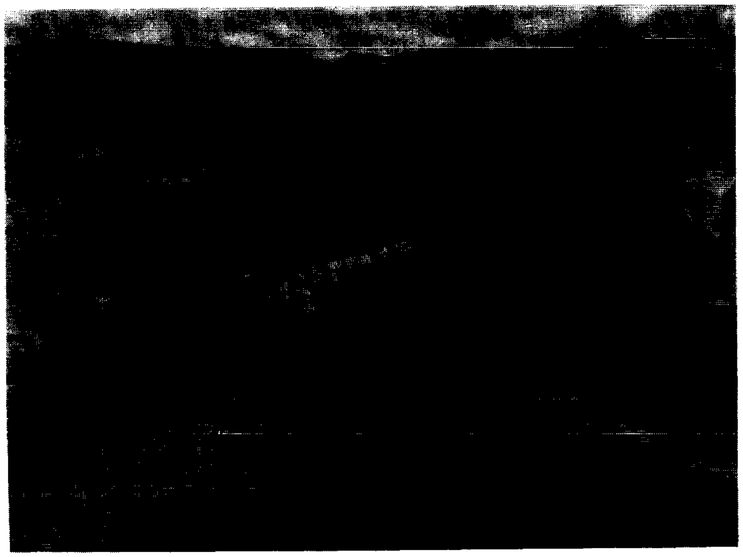

Figure 5: Image of River Valley used in DrawLand Fly-Through.

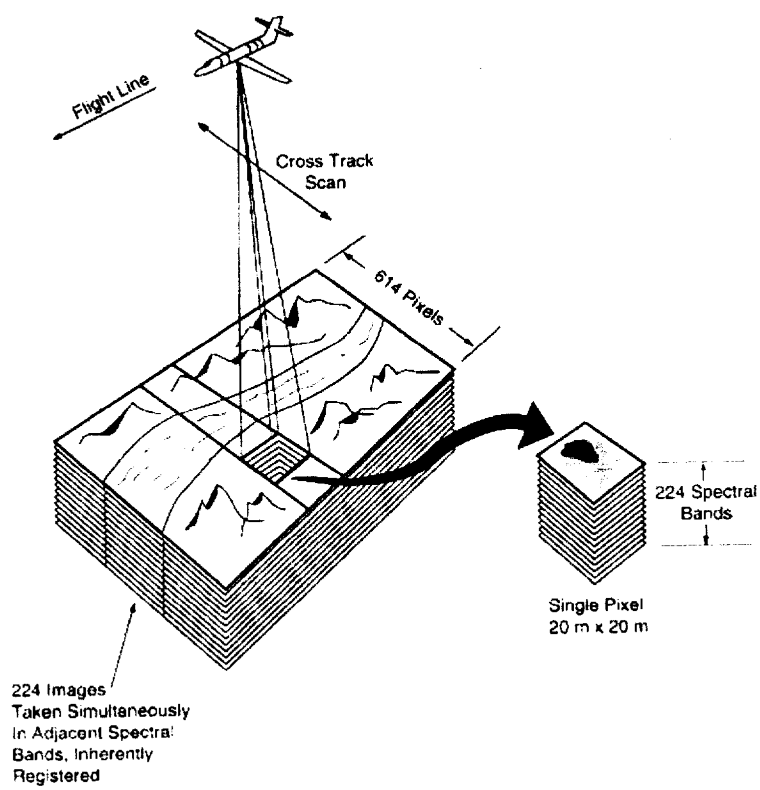

Figure 6: Data Collection Illustration of the AVIRIS Hyperspectral System.

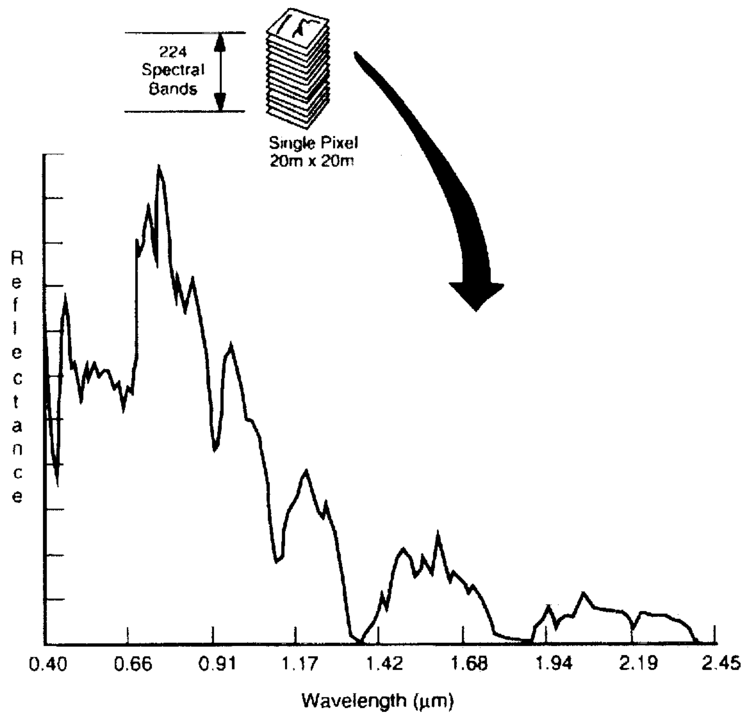

Figure 7: Spectral Distribution from a Single AVIRIS Image Cube.

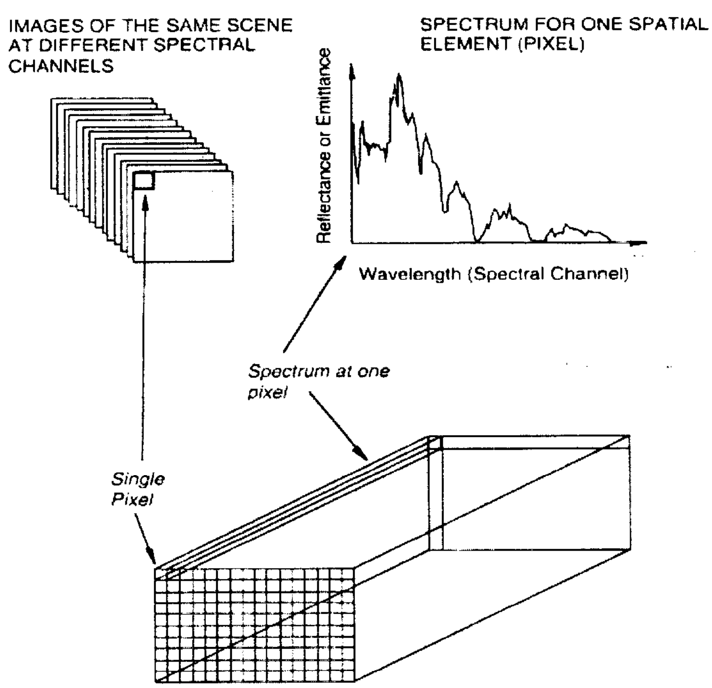

Figure 8: Pixel, Spectral Distribution, and Image Cube, Relationships in a Hyperspectral Analysis.

Figure 9: Mosaic of Landsat Thematic Mapper and AVIRIS Images of a Portion of Big Horn Basin near Worland, WY, U.S.

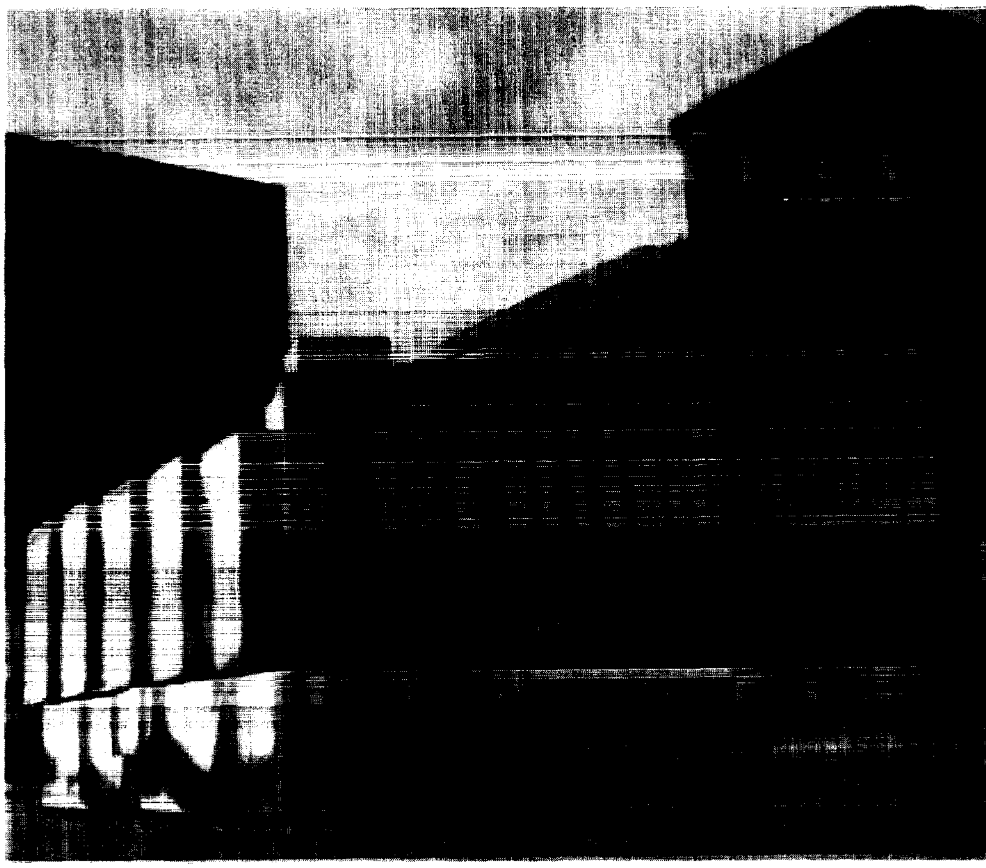

Figure 10: Scene for Geospatial Fly-Through of Rosslyn, VA, using Socet Set Image Exploitation.

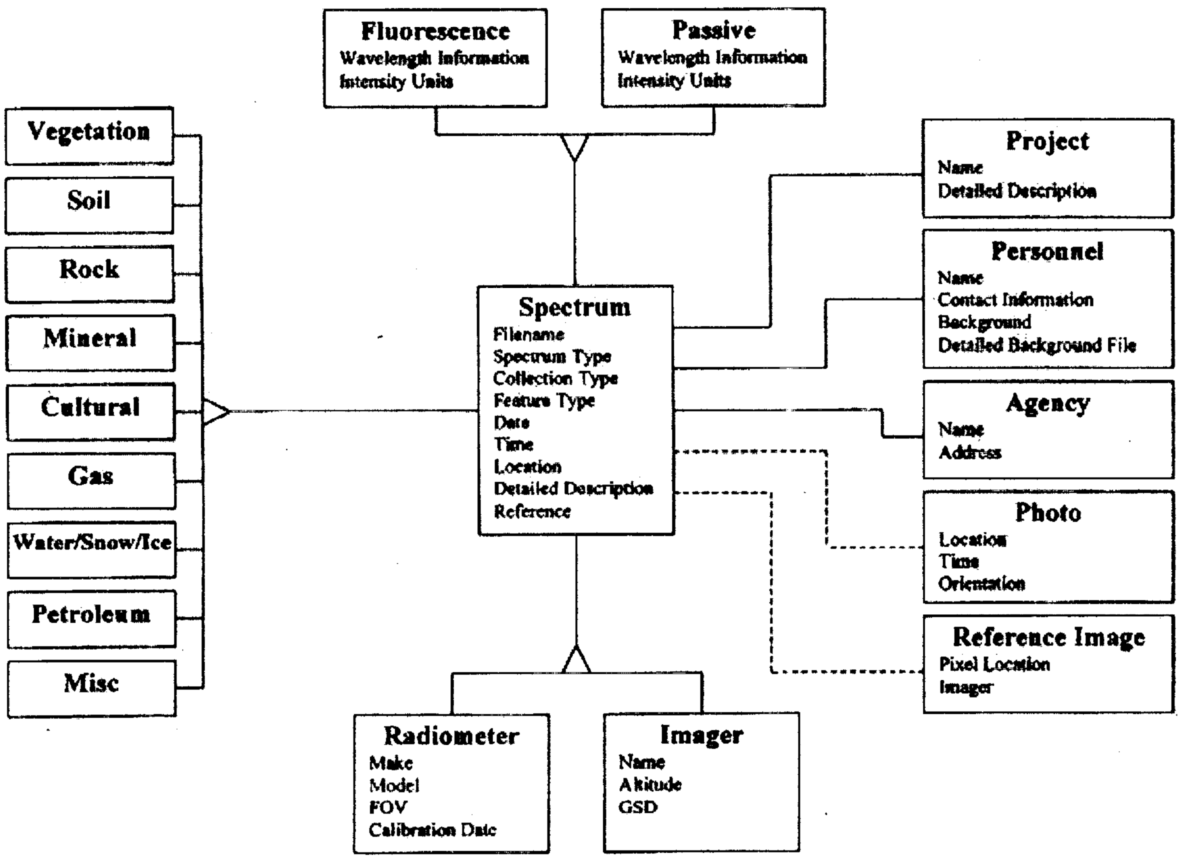

Figure 11a: Framework for the Spectral Library Database Structure.

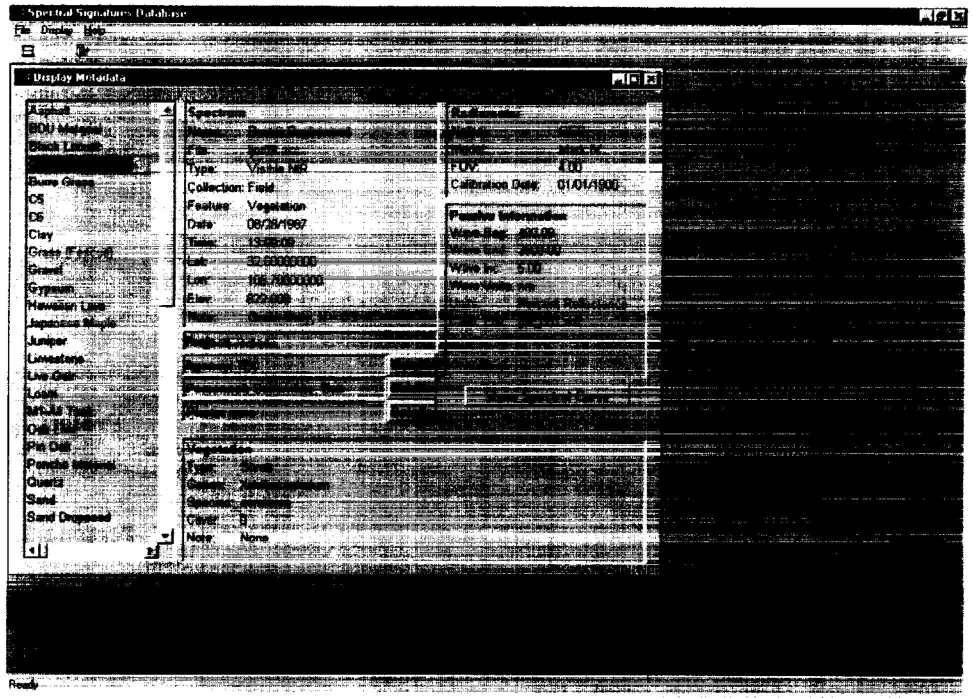

Figure 11b: Prototype Metadata Display.

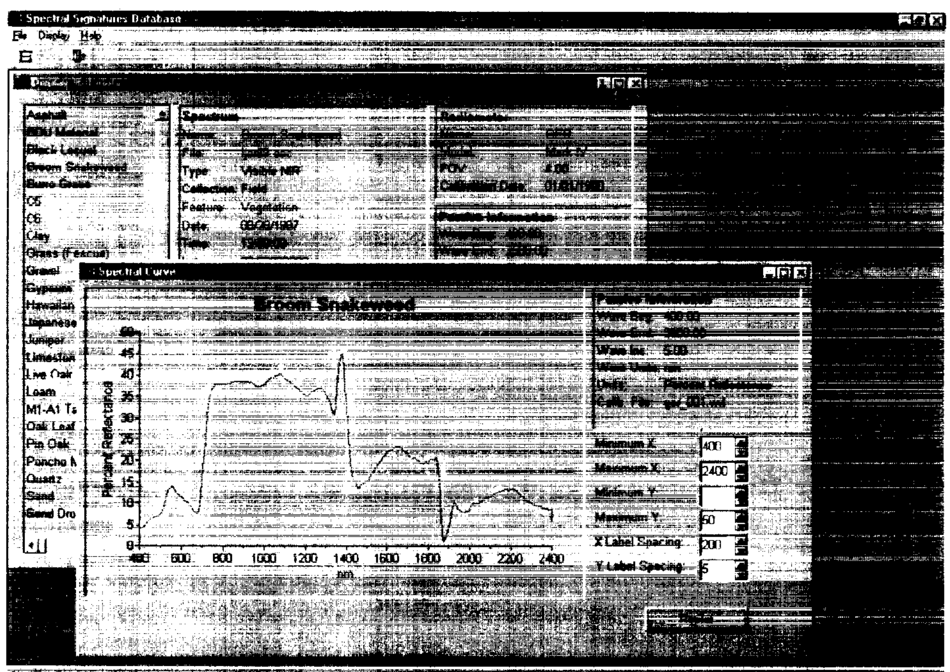

Figure 11c: Prototype Spectral Signature Display.

Figure 12: Digital Multispectral Video (DMSV) image compiled using bands 0.75, 0.65 and 0.55 micrometers. This combination shows the shoreline vegetation as well as the presence or absence of aquatic vegetation.

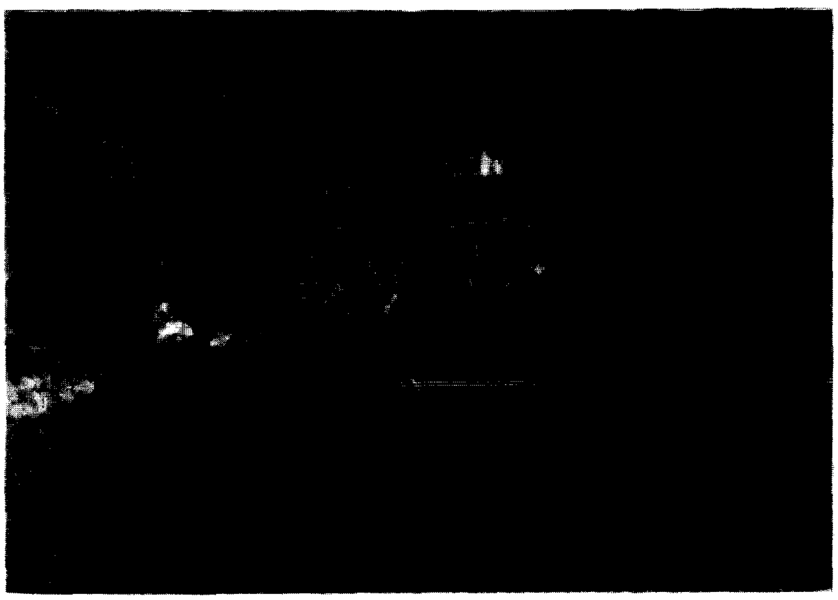

Figure 13: Digital Multispectral Video (DMSV) image using a different combination of bands. Changing the band combinations to 0.77, 0.75 and 0.55 micrometers shows density of aquatic vegetation.

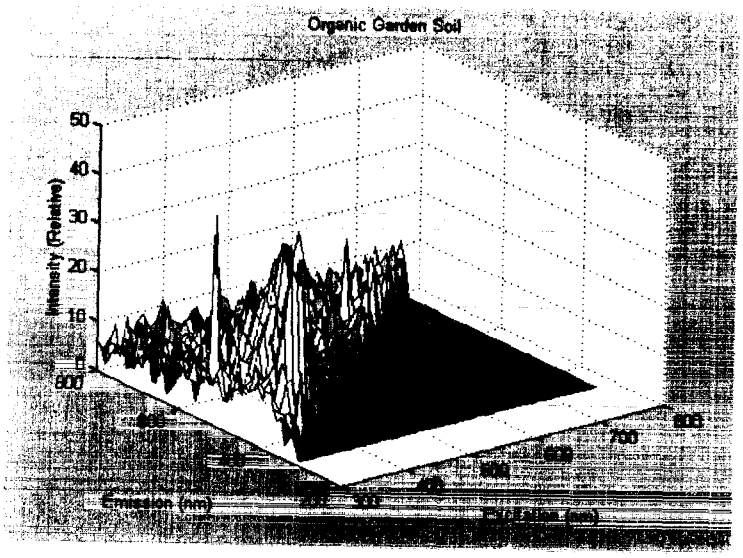

Figure 14a: Fluorescence frequency distribution for organic garden soil.

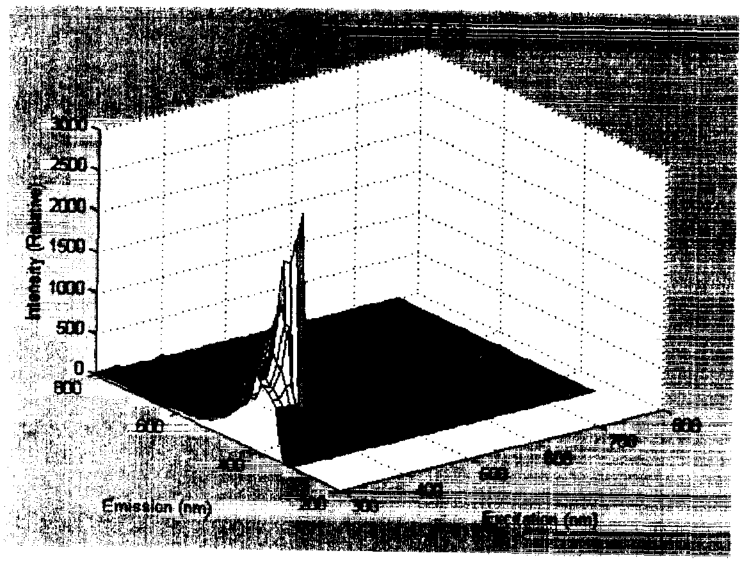

Figure 14b: Fluorescence frequency distribution for the same organic soil mixed with one drop of oil.

Figure 15: Interferometric Synthetic Aperture Radar (IFSAR) image.

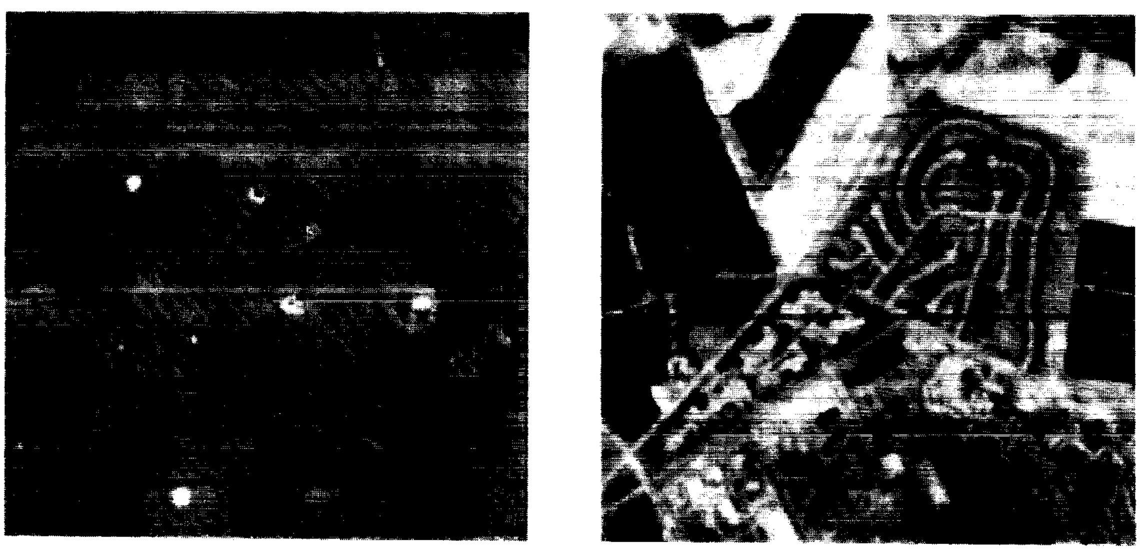

Figure 16: Photogeologic Analysis using 1937 and 1992 Aerial Photo Images.

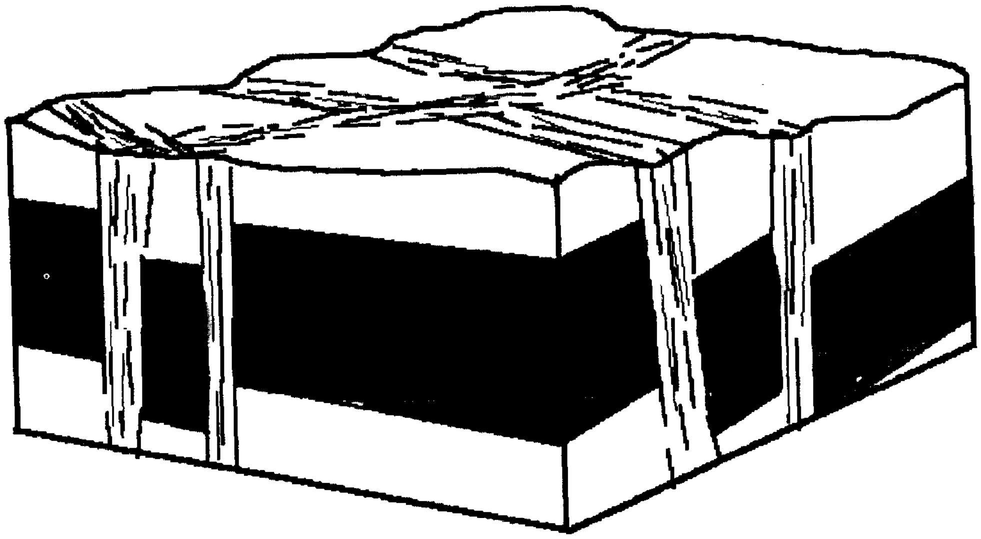

Figure 17: Schematic of Fracture Traces and Lineaments.

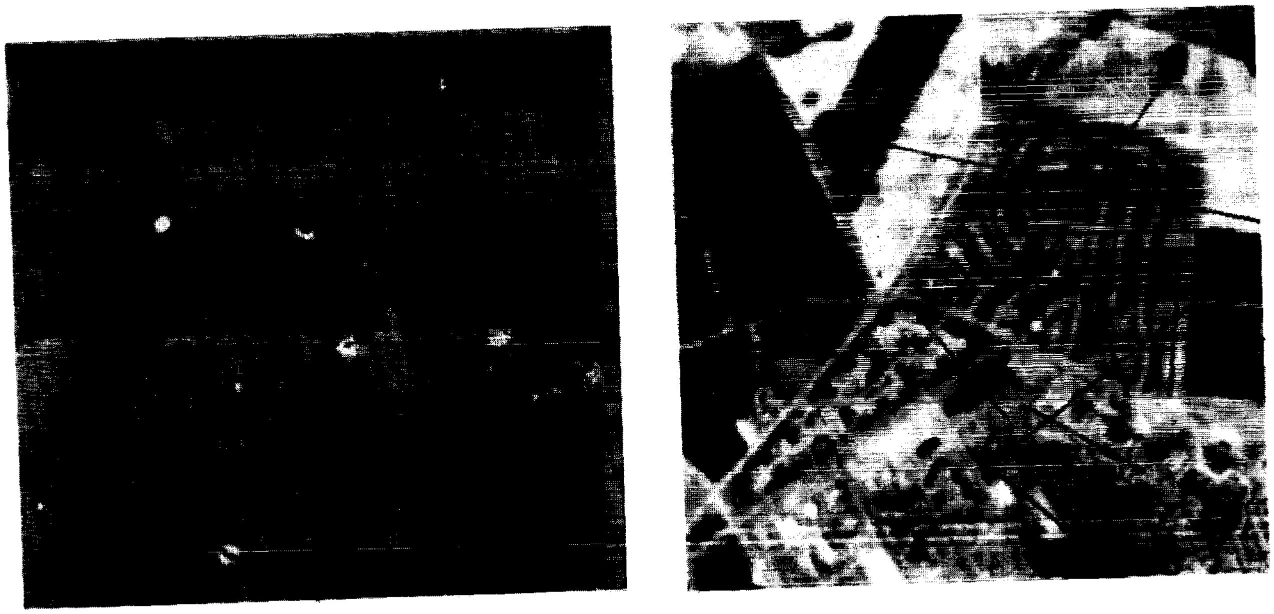

Figure 18: Fracture Trace Analysis and Image Overlays.

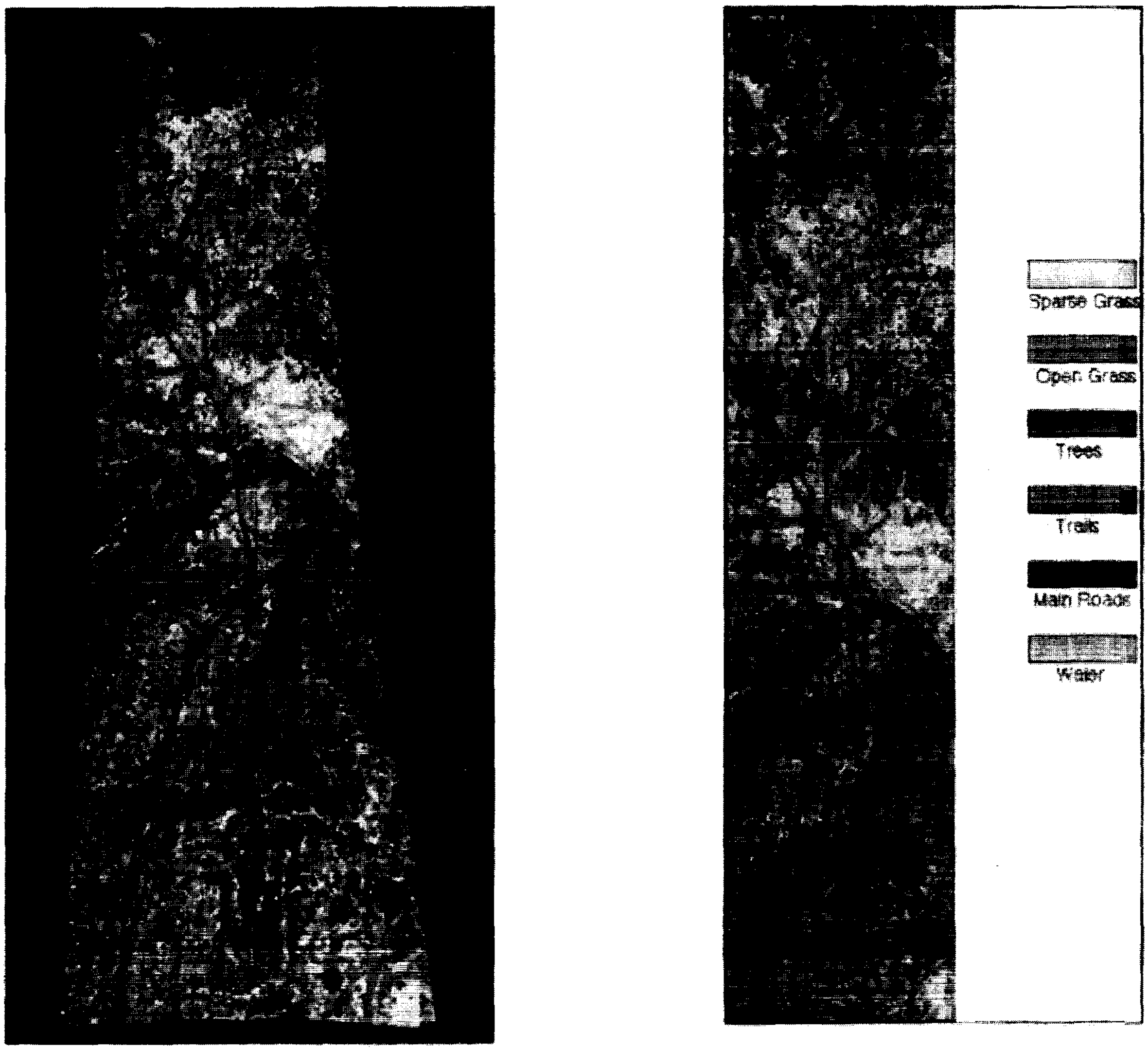

Figure 19: Comparison of a shaded relief image and a 2D land use image.

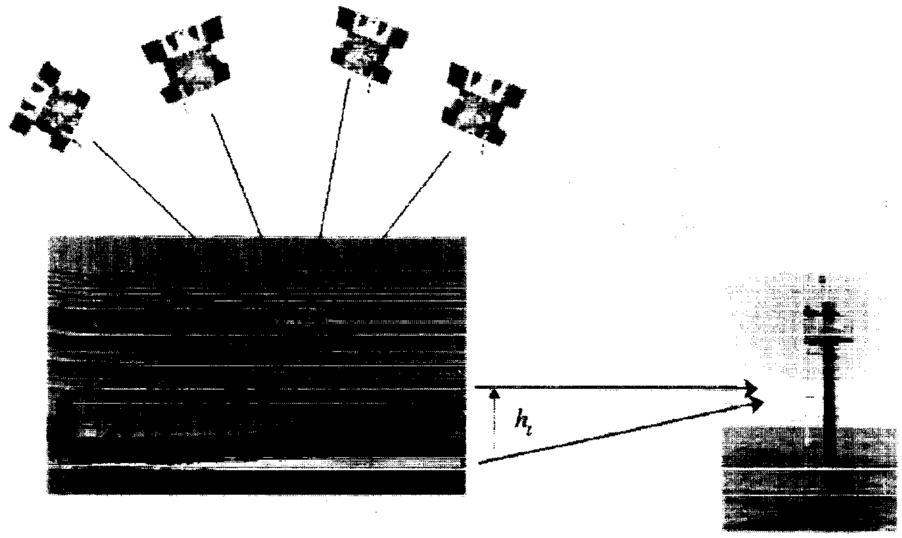

Figure 20: Differential Global Positioning System (GPS) application for precise tide level measurement using the Nav-Star Satellite Constellation.

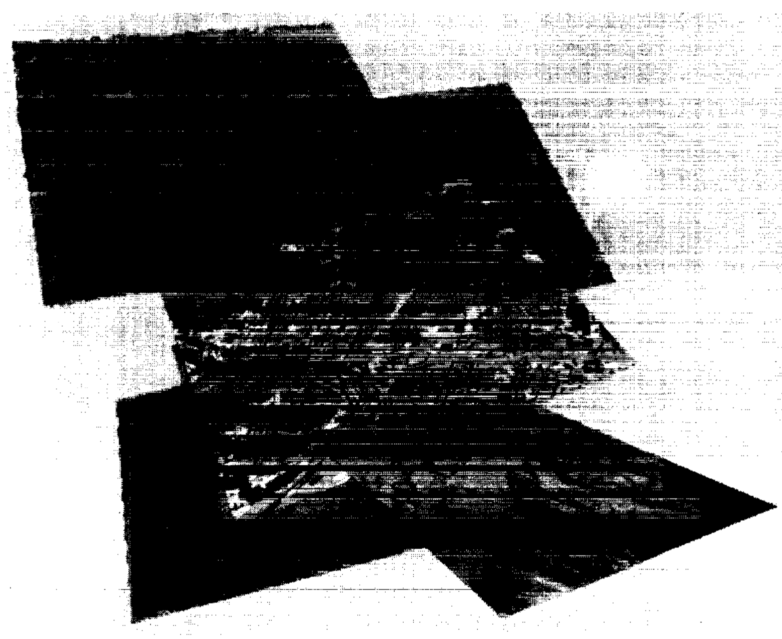

Figure 21: Geographic Information System (GIS) Data Layers.

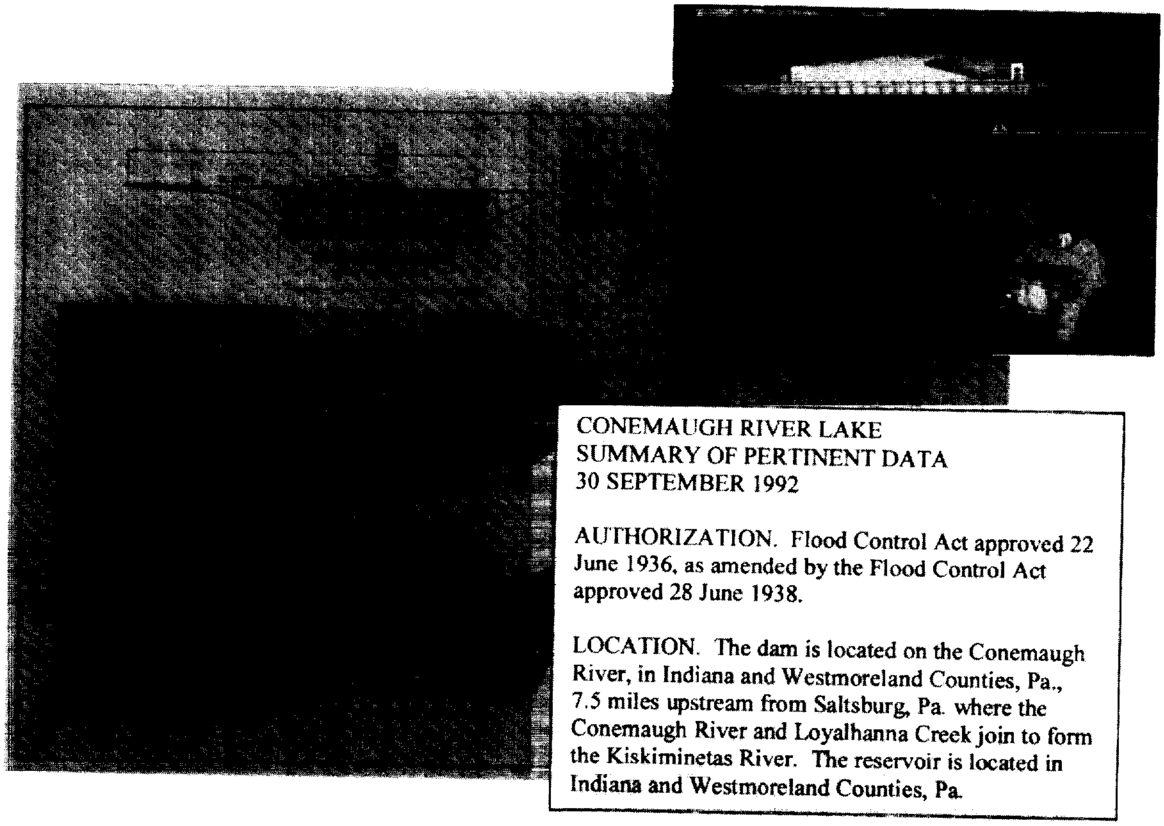

Figure 22: GIS-Based Digital Project Notebook.

Sensor	Spatial Resolution	Revisit Time	Operational Dates	Wavelength Regions	# of Bands
Landsat MSS	80 meter	16-18 days	since 1972	0.50-1.1 um	4
Landsat TM	30 meter	16 days	since 3/84	0.45-2.35 um	6
	120 meter	16 days	since 3/84	10.4-12.4 um	1
SPOT PAN	10 meter	26 days	since 2/86	0.51-0.73 um	1
SPOT XS	30 meter	26 days	since 2/86	0.50-0.89 um	3
Std. Aerial Photo	variable	user-defined	since 1980	B&W, Color IR, Color	
RADARSAT	10-30 meter	2-9 days	since 10/95	C-Band SAR	
IFSAR	5-10 meter	user-defined	since 1995		
Digital Orthophoto	variable	user-defined	since 1980s	user-defined	
Digital MSI Video	0.25 meter potential	user-defined	since 1994	0.35-0.95 um	4
EarthWatch, Inc.		2-3 time/day			
EarlyBird-Pan	3 meter		lost communication	0.45-0.80 um	1
EarlyBird-MSI			lost communication	0.50-0.89 um	3
QuickBird-Pan			launch late 1999	0.45-0.90 um	1
QuickBird-MSI			launch late 1999	0.45-0.90 um	4
Space Imaging, Inc.					
Panchromatic	1 meter	2-4 days	Spring 1998	0.45-0.90 um	1
Multispectral	4 meters			0.45-0.90 um	4

Figure 23: Table of Current Satellite System Availability and Capability.